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(11) **EP 0 970 657 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention  
of the grant of the patent:  
**09.06.2004 Bulletin 2004/24**

(51) Int Cl.7: **A61B 5/103**

(21) Application number: **98202334.3**

(22) Date of filing: **10.07.1998**

(54) **Apparatus and method for measuring the pressure distribution generated by a three-dimensional object**

Gerät und Verfahren zur Messung der durch ein dreidimensionales Objekt erzeugten Druckverteilung  
Appareil et méthode de mesure de la distribution de pression générée par un objet à trois dimensions

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**BE DE FR GB LU NL**

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(43) Date of publication of application:  
**12.01.2000 Bulletin 2000/02**

(56) References cited:  
**WO-A-93/05711**                      **GB-A- 2 256 933**  
**US-A- 5 505 072**                      **US-A- 5 736 656**

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**EP 0 970 657 B1**

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## Description

**[0001]** The present invention relates to an apparatus and a method of measuring the pressure distribution generated by a three-dimensional object, in particular the feet of humans or animals. The present invention is particularly useful in the diagnosis of leg and foot abnormalities and in the selection and design of foot wear.

### TECHNICAL BACKGROUND

**[0002]** Several devices have been designed to measure forces applied by the foot. These include devices for measuring applied forces that are attached to the foot during walking or running, for measuring peak pressure, for measuring the total force applied by the foot, and for measuring forces applied by certain areas of the foot for various purposes. Other devices employ a stationary foot sensor pad and are suited for use in a laboratory or hospital.

**[0003]** Conventional foot force measurement devices function to convert mechanical force into a suitable electrical signal. The types of sensors used include pneumatic or hydraulic fluid activated switches, strain gauge sensors that respond to mechanical deformation, single direct electronic force sensors or multiple direct electronic force sensors.

**[0004]** Pneumatic and hydraulic sensors are prone to produce inaccurate readings because changes in internal pressure are not necessarily proportional to change in forces. One way to construct an accurate fluid sensor is to use rigid plates which limit the applied force to a constant area of fluid contact. In such sensors, the fluid pressure is proportional to the applied force. However, these sensors are disadvantageous due their bulkiness and weight.

**[0005]** The sensors which measure mechanical deformation of structural elements supporting the wearer's foot by use of electrical wire or ribbon type strain gauges accurately measure weight, but they are also disadvantageous because of their bulk and weight.

**[0006]** In direct electronic force sensor devices, the applied pressure compresses a partially conductive material (carbon granules) and thereby reduces its electrical resistance. A force sensor based on this concept can be constructed by forming thin electrodes on two plastic films and then covering the electrodes with a thin layer of suitable partially conductive material. When the two coated films are positioned so that the two layers of partially conductive material are in contact, the electrical resistance through the sensor from electrode to electrode varies inversely with a compressing force on the sensor. This is because as the coating is pressed with greater force, the electrical current path becomes broader due to increased area of contact. This effect occurs with any conductive material, but materials useful as active elements in practical force sensors must have a relatively high electrical resistance. Such thin film elec-

tronic force sensors have the advantages of simplicity, compactness, and light weight, but the disadvantage that they only provide relative indications of pressure applied.

**[0007]** In multiple direct electronic force sensors the sensors may be regularly spaced. Since the relative position of each sensor is fixed, a mathematical description of the location of each sensor can easily be made part of a permanent computer database. These sensor arrays are very thin and very light weight, but they cannot conform to a compound curved surface without wrinkling. Such wrinkled or folded thin film sensor arrays may produce erroneous results. A wrinkled sensor array may produce an electrical signal from the wrinkle alone. Folding or wrinkling also subjects the sensor array to severe fatigue stress, which can lead to early and sudden failure.

**[0008]** A practical sensor array preferably includes a large number of individual force sensors. The problem of electrically connecting this number of individual sensors to data acquisition circuitry is a significant one. Preferably a two-vector array of rows and columns is provided with a top electrode of all sensors in each column commonly connected and a bottom electrode of all the sensors in each row likewise commonly connected.

**[0009]** Insole force sensor arrays are described in US 5,408,873 and US 5,678,448. In addition, alternative apparatuses makes use of a flat pressure sensor array onto which the person places his or her foot as disclosed, for example, in US 5,659,395. Typically the pressure sensor array may be provided by a large number of resistive pressure sensors. This flat plate arrangement has the advantage that there is no bending or folding of the pressure pad which makes the design of the pressure sensors somewhat simpler and allows a high density and a high number of individual pressure sensors to be included within the pressure pad.

**[0010]** Independent of whether an insole pressure device is used or a flat plate, the use of resistive pressure sensors is convenient and provides a light weight apparatus. However, the major disadvantage of resistive pressure sensors is that they are not absolutely calibrated but rather provide relative pressure values. In addition it is possible, through use, that pressure sensors in one area of a pressure path may alter their response characteristic with time. Calibrating or re-calibrating the multitude of pressure sensors in a pressure pad is not only time consuming but also difficult to carry out exactly. US-A-5 736 656 discloses such an apparatus for measuring the pressure distribution, which requires regular calibration using force loading machines. Moreover, in some devices the pressure pad is not absolutely rigid, it is difficult to apply a uniform pressure to individual or groups of sensors.

**[0011]** It is an object to the present invention to provide a pressure distribution sensing apparatus and method for sensing the pressure distribution of a three-dimensional object which avoids or reduces the prob-

lems of calibration or re-calibration of pressure known pressure pads.

**[0012]** It is a further object of the present invention to provide a force sensing apparatus which is light in weight and is convenient to use for determining the pressure distribution generated by a three-dimensional object.

#### SUMMARY OF THE INVENTION

**[0013]** The present invention includes a self-calibrating apparatus for measuring the pressure distribution generated by a three-dimensional object, comprising : a plurality of first non-linear force sensors arranged in an array; and a second force sensing device having a linear or linearisable output for measuring the total force applied to the first force sensors.

**[0014]** The present invention includes an apparatus for measuring the pressure distribution generated by a three-dimensional object, comprising : a substantially rigid plate; a plurality of first force sensors arranged in an array, the array of first force sensors being arranged to be on one side of the plate; and a second force sensing device for measuring the total force applied to the plate.

**[0015]** The present invention may also include a method of measuring the pressure distribution generated by a three-dimensional object, comprising the steps of : providing a plurality of first non-linear force sensors arranged in an array; providing a second force sensing device having a linear or linearisable output for measuring the total force applied to the first force sensors; obtaining readings of the force on each sensor of the array of first pressure sensors; adding together the readings from all the first force sensors in the array and comparing this result with the output of the second force sensing device.

**[0016]** The present invention may also include a method of measuring the pressure distribution generated by a three-dimensional object, comprising the steps of: providing a substantially rigid plate; providing a plurality of first force sensors arranged in an array, the array being arranged to be on one side of the plate; providing a second force sensing device for measuring the total force applied to the plate; scanning the array of first force sensors to obtain readings of the force on each sensor; adding together the readings from all the first force sensors in the array and comparing this result with the output of the second force sensing device.

**[0017]** The present invention may provide the advantage that the relative pressure measurements generated by a resistive pressure pad may be continuously and dynamically calibrated by means of a second force sensing device. The second force sensing device is preferably one which is easily calibrated, is linear in its output and is stable. Preferred second sensor devices are an array of strain gauge force sensing devices, piezo-resistive or piezo-electric sensing devices. Preferably

the second sensors are read out in parallel. The most preferred second sensing device is one or more piezo-electric sensors.

**[0018]** The dependent claims define individual and separate embodiments of the present invention. The present invention will now be described with respect to the following drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

**[0019]**

Fig. 1 is a schematic representation of a pressure distribution sensing apparatus in accordance with a first embodiment of the present invention.

Fig. 2 is a schematic cross-sectional representation of a pressure plate in accordance with an embodiment of the present invention.

Fig. 3 is a further schematic representation of the pressure distribution sensing apparatus in accordance with the first embodiment of the present invention.

Fig. 4 is a representation of a look-up table for calibration factors in accordance with an embodiment of the present invention.

Figs. 5A and 5B show representative outputs of the force sensors of the present invention, before and after a first calibration.

Fig. 6 shows a representation of the outputs from one row or column of force sensors.

Fig. 7 is a schematic representation of a pressure distribution sensing apparatus in accordance with a second embodiment of the present invention

#### DESCRIPTION OF THE ILLUSTRATIVE EMBODIMENTS

**[0020]** The present invention will be described in the following mainly with respect to a device for measuring the pressure and/or force on the feet of human beings or animals during walking, running, jumping or standing. The invention is not limited thereto but may be used for the measurement of the pressure distribution generated by any three-dimensional object. Further, the present invention will be described mainly with respect to the use of an array of resistive force sensors, but the present invention is not limited thereto. Alternative force sensing devices may be used, for instance capacitive or inductive force sensing devices. Further, the present invention will be described mainly with respect to the use of piezo-electric sensors as the second sensing device for measuring the total force on the intermediate plate. The present invention is not limited thereto but includes other force or pressure sensing devices, in particular strain gauge and piezo-resistive force sensing devices with analogue or digital readouts.

**[0021]** Fig. 1 is a schematic representation of a first embodiment of a pressure distribution sensing appara-

tus 10 in accordance with the present invention. It includes a substantially flat pressure sensing plate 1 which includes force sensing devices which will be described later, a means 8 for transmitting the individual the values of the force sensors in plate 1 representing the force applied to them to suitable read out electronics 4 and processing and storage electronics 9 including an optional display 11. Transmission means 8 may include cables, optical, e.g. infrared, microwave transmission devices or similar, i.e. the present invention includes both a direct connection between plate 1 and read out electronics 4 via cables as well as remote connection via any form of electromagnetic radiation.

**[0022]** Fig. 2 is a schematic detailed cross-sectional representation of one embodiment of the pressure sensing plate 1 shown in Fig. 1. Fig. 3 includes a schematic top view of one arrangement of sensors 2, 3 in accordance with the present invention. Sensing plate 1 includes a plurality of impedance sensing devices 2 arranged in a regular two-dimensional array. Sensors 2 are preferably resistive sensors but may also be capacitive or inductive sensors. Connections 12, 13 are provided for measuring the resistance of each individual sensing device 2 and outputting this as a signal. Resistive sensors generally have a non-linear force/resistance characteristic. There may be several thousand resistive sensing devices 2 arranged in an array of rows and columns or a similar organised structure and the sensors 2 are preferably distributed evenly over plate 1. The position of each sensor 2 on the plate 1 is preferably known and this position is stored in the electronics 9 and associated with the specific sensor 2. Force sensing devices 2 may be formed from a single sheet of resistive material 7 and covered by a suitable outer thin flexible layer (not shown). Underneath layer 7, a substantially rigid plate 5 is provided which may be several millimetres thick and made of a suitable rigid material such as steel or rigid plastic. One or more second force sensing devices 3 are provided which co-operate with plate 5 so that the total downward force on plate 5 is equal to the sum of the outputs of the second sensors 3. The positions of the second sensing devices 3 relative to plate 1 are optionally also stored in the electronics 9. Optionally, a further support plate 6 may be provided on which the second force sensing devices 3 are located.

**[0023]** Plate 1 is placed on a suitable flat object such as a floor in such a way that when a three-dimensional object is placed on the surface of plate 1 the local pressure exerted by the object influences the output of each of the plurality of first force sensing devices 2. As the total force on the plate 1 is measured by the sum of the outputs of the one or more second force sensing devices 3 the sum total of all the outputs of the force sensing devices 2 should equal the sum total of the outputs of the second sensing devices 3. Any difference in these totals is an indication that the calibration of the first force sensors 2 is incorrect. Typically, fewer second force sensing devices 3 are provided than first sensors 2, e.

g. one centrally placed sensor up to several hundred or more may be provided,. Sensors 3 are preferably distributed equally over plate 1. Second force sensing devices 3 may be considerably larger in diameter than the force sensing devices 2 and are preferably of the type which can be easily calibrated, provide a linear output or a linearisable output with respect to the force applied and are stable over time. By linearisable output is meant that the second type of force sensor 3 may have a non-linear output but this is sufficiently reproducible that it can be linearised by suitable electronics either in the sensor itself or incorporated in the measuring electronics 4, 9. Preferred second force sensing devices 3 are piezo-electric sensors supplied, for instance, by Kistler of Switzerland.

**[0024]** As best shown in Fig. 3 the array of first sensors 2 are connected to the scanning electronics 4 by means of connecting lines 12, 13. It is possible to read out all the sensors 2 in parallel, however for large size arrays (10,000 sensors or more) it is more practical to read out the sensors 2 in sequence using addressing lines 12, 13 with which each one of the sensors may be addressed by placing a voltage on each of the respective lines 12, 13 which intersect at the desired sensor 12. The ratio of applied voltage to current flowing provides a measure of the resistance of the sensor 2 and hence an indication of the applied force. The analogue result is converted to digital signals in scanning means 4. Second sensors 3 are preferably read out in parallel which requires a connection 14 to each sensor 3 (not all connections shown in Fig. 3 to avoid confusion). It is preferable to read out all second sensors 3 in parallel so that the sum of all outputs of the sensors 3 is available from one instant of time. This means that the instantaneous force applied to the plate 1 can be calculated from the sum of the read outs of all sensors 3 at one instant. It is preferred if the rate of reading out sensors 3 is high, e.g. several thousand times per second so that dynamic changes of foot loading on plate 1 can be tracked accurately. The scanning rate of the array of first resistive sensors 2 may be lower, e.g. a complete scan of all sensors 2 may be completed several hundred times per second. As the scan of the array of first sensors 2 is sequential, the picture of the pressure distribution is not instantaneous but is spread over the time for one scan. This time period is preferably still very small, i.e. of the order of thousandths or hundredths of a second so that the pressure distribution on plate 1 is effectively "frozen" over one scan of sensors 2.

**[0025]** Referring now to FIG. 3, which only shows one possible implementation of the present invention, the array of force sensors 2 is connected to measuring electronics 4, 9, which contains scanning circuitry 4 controlled by a central processing unit (CPU) 22. CPU 22 executes software routines stored in a read-only memory (ROM) 23 during system boot up and thereafter executes software programs stored in a random access memory (RAM) 25. An interface 24 is used to upload

data stored in RAM 25 to an external personal computer (PC) 27 and to down-load operational data and software programs from the PC 27 to RAM 25. A clock 26 provides time and date information to CPU 22. Non-volatile read-write memory 28 may also be provided to store data which is to survive power down and boot up.

**[0026]** The resistance of each force sensor 2 of the array of force sensors 2 is inversely proportional to the applied force and the response is non-linear and may vary between individual sensors 2 due to unavoidable manufacturing variances. To provide some adjustment because of these manufacturing tolerances and non-linear effects, a two-vector data array may be stored within the RAM 25 previously loaded into non-volatile memory 28 by use of a PC and other suitable test equipment. In this array, a first vector applies to each sensor 2, and a second vector applies to each possible resistance value of a particular sensor. Contained in each storage location within the data array is the appropriate output value. The information stored in the data array for a particular sensor 2 currently being evaluated is used to translate the measured characteristic (e.g. resistance) of the individual sensor 2 to a value representing the force being placed on the sensor. Each sensor 2 is scanned in turn, its value translated, and each translated value is added to the value representing the total force measured by the array of force sensors 2. Following a single scan of the complete array of force sensors 2, the total force on the array force of sensors 2 is available as well as the value from each sensor 2 which may be used to create a graphical image of the pressure distribution on the display 11. The total force value computed from the outputs of sensors 2 is compared with the values obtained from the second force sensors 3. Any difference indicates that a further correction or calibration of the force sensors 2 is required.

**[0027]** The method of using the pressure distribution sensing apparatus 10 of Figs. 1 - 3 will now be described. Initially, the second pressure sensing devices may be calibrated. This may be done individually before placing the sensors 3 in the device 10 and/or by applying a known weight to pressure plate 1, e.g. 50 kilograms. As the sum total of the signal outputs of the second pressure sensing devices 3 should equal the total force on plate 1, the sum total of the outputs of the second sensory devices 3 can be calibrated against the known weight. Smaller weights may be distributed over the surface of plate 1 to obtain further information about the calibration of both the first and second sensors 2, 3 however this is not essential. The force sensors 2 have a non-linear output and measuring electronics 4, 9 includes means for converting the non-linear output of these senses into accurate force readings. This may be done by multiplying the output of sensor 2 obtained after translation by a factor which converts the output into an absolute force reading. The necessary conversion factors may be included in a look-up table as shown schematically in Fig. 4. The present invention is not limited

to look-up tables and a skilled person is aware of alternative methods of linearising the output of a force sensor. The look-up table includes a calibration factor for each of a plurality of output values of the sensors 2. The more calibration factor values are stored in the look-up table, the more accurate is the conversion of the measured outputs. Initially the calibration factor values may all be set to one specific value or to what are considered to be suitable values. The apparatus 10 in accordance with the present invention is self-calibrating so that these initial values are not of great importance. A dynamic load is now placed upon the plate 1 and the sum of all the translated outputs of the sensors 2 is compared with the sum of all the outputs of sensors 3 at different times. Fig. 5A is a schematic representation of a loading on plate 1 in which each point on the lower curve is the sum total of all the outputs from the array of sensors 2 in one scan and each point on the upper curve is the sum total of the outputs from the force sensing device 3. Initially as shown in Fig. 5A, the translation values in the two-vector data array of the force sensors 2 are not accurate and there is a difference between the sum total of outputs from sensors 2 and sensors 3. The ratio of these outputs provides a calibration factor for the sensors 2. This calibration value is available only for one force i.e. the average force on plate 1 during that scan. In accordance with the one embodiment of the present invention the translation values for this particular force in the two-vector data array for all the sensors 2 are multiplied by the calibration factor. As the calibration factor for each new force is determined, the look-up table is updated for this particular force with the determined calibration factor and all the translation values in the two-vector array for this force are multiplied by the calibration factor. Hence, as the load on plate 1 varies, further calibration factors for other forces are determined in this way. Note, that as the sum total of the outputs of the sensors 2 in one complete scan are made up of different forces, the calibration factors determined by the above method after one load cycle of plate 1 is not perfect. As shown in Fig. 5B, after one load cycle, the gap between the two curves is smaller but not eliminated. However, with more load cycles, the approximations become more and more accurate until the final output displayed on the display 11 is absolute pressure values and not relative ones.

**[0028]** This process of self-calibration is dynamic, i.e. if the non-linear characteristic of the sensors 2 alters because of change of temperature, for instance, these changes will be detected by differences between the sum totals of the outputs of sensors 2 of the array and the sum totals of the outputs of sensors 3 and appropriate changes made to the calibration factors. At the end of a significant number of load cycles the calibration factors in the look-up table are preferably stored in non-volatile memory for use as the initial values at the start of the next test run.

**[0029]** One disadvantage of the above embodiment

of the present invention is that the calibration factors for sensors 2 are global, i.e. they are applied to all the sensors 2 uniformly rather than providing individual calibration factors for each individual sensor 2. The present invention also includes providing calibration factors for individual sensor 2 or groups of sensors 2. One way of providing individual calibration factors will be described with respect to Fig. 6. In order to provide individual calibration factors for each sensor it is necessary to have a look-up table for each sensor, i.e. to provide a second two-vector array in which one vector points to the sensor to be evaluated and the other vector points to the output value of the sensor. The data located at this address in the array provides the calibration factor for the sensor. Generally, if the outputs of one row or one column of the array of sensors 2 are analysed (Fig. 6) they will provide a relatively smooth function. This may require that there are no very sharp edges on the object which is being measured. This is generally true for the feet of humans. It is generally possible to fit the individual values of sensors 2 obtained from one row or one column to a smooth curve using a suitable curve fitting algorithm. For instance the output of one row or one column may be fitted with a third order polynomial using a least squares curve fitting technique. The difference between the calculated curve and each individual sensor output may be determined by subtraction and these error values converted into a standard deviation  $\sigma$ . The deviation between each individual output in the row or column and the best fit curve is then compared with the standard deviation  $\sigma$  and any output which shows a significant deviation, i.e. greater than  $3\sigma$ , indicates that the calibration factor for this sensor 2 and for this force must be altered. Hence, the calibration factor for that force is amended in the second two-vector array for that particular sensor. The number of times a sensor 2 has values which exceed the standard deviation  $\sigma$  by a significant amount may also be stored which may give an indication of a sensor 2 which has erratic behaviour, e.g. a poor contact.

**[0030]** Fig. 7 is a schematic representation of a second embodiment of a pressure distribution measuring apparatus 10 in accordance with the present invention. The major distinction between the second and first embodiments of the present invention is that the array of sensors 2 in accordance with the second embodiment need not be included within pressure plate 1 but may be included in an insole array. The array of sensors 2 is positioned relative to a user's foot thus allowing the measurement of the forces applied by the foot while the user is standing, walking, jumping or running. Such an array of non-linear resistive elements is disclosed, for instance, in US 5,678,448. The sensors 2 of the insole array may be non-linear resistive sensors as described for the first embodiment. Preferably there is an interconnection means 18 between the insole array of sensors 2 and the measuring electronics 4, 9 which does not impede a movement of the user. For instance, a remote transmission method may be used such as infrared or

microwave transmission.

**[0031]** The operation of the measuring apparatus 10 in accordance with the second embodiment is, in principle, the same as for the first embodiment. The insole array of sensors 2 is read out in a sequential fashion whereas the second sensing devices 3 associated with pressure plate 1 are read out in parallel at high frequency. Pressure plate 1 for the second embodiment can be identical to the pressure plate 1 for the first embodiment except for the fact that there need be no connection between the arrays of pressure sensors 2 associated with plate 1 and the measuring electronics 4, 9. Instead, the sensors 2 of the insole array are connected to the measuring electronics 4, 9. The self-calibrating procedure described with respect to the first embodiment may also be applied to the second embodiment so that the sum total of the outputs from the sensors 2 of the insole array is compared with the total output of the second sensing devices 3 after each scan of the complete insole array. Any difference between these two is compensated for by amending the calibration factors in the look-up table or the second two-vector data array as has been described with respect to the first embodiment.

## Claims

1. A self-calibrating apparatus for measuring the pressure distribution generated by a three-dimensional object, comprising :
  - a plurality of first non-linear force sensors (2) arranged in an array; and
  - a second force sensing device (3) having a linear or linearisable output for measuring the total force applied to the first force sensors.
2. An apparatus for measuring the pressure distribution generated by a three-dimensional object, comprising :
  - a substantially rigid plate (1),
  - a plurality of first force sensors (2) arranged in an array, the array of first force sensors being arranged to be on one side of the plate; and
  - a second force sensing device (3) for measuring the total force applied to the plate.
3. An apparatus according to claim 1 or 2, further comprising a device (4, 9) for calculating the total force applied to all the first sensors in the array and to calculate the total force applied to the second sensing device and for comparing the two results.
4. An apparatus according to claim 3, further comprising a device for calibrating the first force sensors depending on the result of the comparison.

5. An apparatus according to any previous claim, wherein the array of first sensors is included in one pressure sensing device and the second sensing device is included in a second pressure sensing device.

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6. An apparatus according to any previous claim, further comprising a device for determining an individual calibration factor of each first sensor.

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7. A method of measuring the pressure distribution generated by a three-dimensional object, comprising the steps of:

providing a plurality of first non-linear force sensors arranged in an array;  
 providing a second force sensing device having a linear or linearisable output for measuring the total force applied to the first force sensors;  
 obtaining readings of the force on each sensor of the array of first pressure sensors;  
 adding together the readings from all the first force sensors in the array; and  
 comparing this result with the output of the second force sensing device.

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8. A method of measuring the pressure distribution generated by a three-dimensional object, comprising the steps of:

providing a substantially rigid plate;  
 providing a plurality of first force sensors arranged in an array, the array being arranged to be on one side of the plate;  
 providing a second force sensing device for measuring the total force applied to the plate;  
 scanning the array of first force sensors to obtain readings of the force on each sensor;  
 adding together the readings from all the first force sensors in the array; and  
 comparing this result with the output of the second force sensing device.

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9. A method according to claim 7 or 8, further comprising the step of calibrating the first force sensors depending on the result of the comparison.

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10. A method according to any of claims 7 to 9, further comprising the step of determining an individual calibration factor for each first sensor.

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### Patentansprüche

1. Selbstkalibrierungsvorrichtung zur Messung der durch ein dreidimensionales Objekt erzeugten Druckverteilung mit:

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einer Vielzahl an in einem Feld angeordneten ersten nicht-linearen Kraftsensoren (2); und mit einer zweiten Kraftmesseinrichtung (3) mit einer linearen oder linearisierbaren Ausgabe zum Messen der an die ersten Kraftsensoren angelegten Gesamtkraft.

2. Vorrichtung zur Messung der durch ein dreidimensionales Objekt erzeugten Druckverteilung mit:

einer im Wesentlichen starren Platte (1); einer Vielzahl an in einem Feld angeordneten ersten Kraftsensoren (2), wobei das Feld der ersten Kraftsensoren auf einer Seite der Platte befindlich angeordnet ist; und mit einer zweiten Kraftmesseinrichtung (3) zum Messen der an die Platte angelegten Gesamtkraft.

3. Vorrichtung nach Anspruch 1 oder 2, **dadurch gekennzeichnet, dass** sie ferner eine Einrichtung (4, 9) zum Berechnen der an alle ersten Sensoren in dem Feld angelegten Gesamtkraft und zum Berechnen der an die zweite Messeinrichtung angelegten Gesamtkraft und zum Vergleichen dieser beiden Ergebnisse aufweist.

4. Vorrichtung nach Anspruch 3, **dadurch gekennzeichnet, dass** sie ferner eine Einrichtung zum Kalibrieren der ersten Kraftsensoren in Abhängigkeit des Ergebnisses des Vergleichs aufweist.

5. Vorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** das Feld der ersten Sensoren in einer Druckmesseinrichtung enthalten und dass die zweite Messeinrichtung in einer zweiten Druckmesseinrichtung enthalten ist.

6. Vorrichtung nach einem der vorangehenden Ansprüche, **dadurch gekennzeichnet, dass** sie ferner eine Einrichtung zum Bestimmen eines individuellen Kalibrierungsfaktors jedes ersten Sensors aufweist.

7. Verfahren zur Messung der durch ein dreidimensionales Objekt erzeugten Druckverteilung mit folgenden Schritten:

Liefern einer Vielzahl an in einem Feld angeordneten ersten nicht-linearen Kraftsensoren; Liefern einer zweiten Kraftmesseinrichtung mit einer linearen oder linearisierbaren Ausgabe zum Messen der an die ersten Kraftsensoren angelegten Gesamtkraft;

Erhalten von Anzeigen der auf jeden Sensor des Feldes der ersten Drucksensoren wirkenden Kraft;  
 Zusammenaddieren der Anzeigen von allen er-

sten Kraftsensoren in dem Feld; und  
Vergleichen dieses Ergebnisses mit der Ausgabe der zweiten Kraftmesseinrichtung.

8. Verfahren zur Messung der durch ein dreidimensionales Objekt erzeugten Druckverteilung mit folgenden Schritten:

Liefere einer im Wesentlichen starren Platte;  
Liefere einer Vielzahl an in einem Feld angeordneten ersten Kraftsensoren, wobei das Feld auf einer Seite der Platte befindlich angeordnet wird;  
Liefere einer zweiten Kraftmesseinrichtung zum Messen der an die Platte angelegten Gesamtkraft;  
Abtasten des Felds der ersten Kraftsensoren zum Erhalten von Anzeigen der auf jeden Sensor wirkenden Kraft;  
Zusammenaddieren der Anzeigen von allen ersten Kraftsensoren in dem Feld; und  
Vergleichen dieses Ergebnisses mit der Ausgabe der zweiten Kraftmesseinrichtung.

9. Verfahren nach Anspruch 7 oder 8, **dadurch gekennzeichnet, dass** es ferner den Schritt des Kalibrierens der ersten Kraftsensoren in Abhängigkeit des Ergebnisses des Vergleichs aufweist.

10. Verfahren nach einem der Ansprüche 7 bis 9, **dadurch gekennzeichnet, dass** es ferner den Schritt des Bestimmens eines individuellen Kalibrierungsfaktors für jeden ersten Sensor aufweist.

#### Revendications

1. Appareil à auto-étalonnage, destiné à la mesure de la répartition de pression, produite par un objet tridimensionnel, et comprenant :

une pluralité de premiers capteurs non linéaires de force (2), disposés en un groupement ; et  
un second dispositif de détection de force (3), ayant une sortie linéaire ou linéarisable, pour la mesure de la force totale appliquée aux premiers capteurs de force.

2. Appareil destiné à la mesure de la répartition de pression, produite par un objet tridimensionnel, et comprenant :

une plaque (1) sensiblement rigide ;  
une pluralité de premiers capteurs de force (2), disposés en un groupement, le groupement des premiers capteurs de force étant prévu pour être placé sur un côté de la plaque ; et  
un second dispositif de détection de force (3),

servant à mesurer la force totale appliquée à la plaque.

3. Appareil selon la revendication 1 ou 2, comprenant en outre un dispositif (4, 9) servant à calculer la force totale appliquée à tous les premiers capteurs du groupement, et à calculer la force totale appliquée au second dispositif de détection, ainsi qu'à comparer les deux résultats.

4. Appareil selon la revendication 3, comprenant en outre un dispositif pour l'étalonnage des premiers capteurs de force, en fonction des résultats de la comparaison.

5. Appareil selon l'une quelconque des revendications précédentes, dans lequel le groupement de premiers capteurs est inclus dans un dispositif de détection de pression, tandis que le second dispositif de détection est inclus dans un second dispositif de détection de pression.

6. Appareil selon l'une quelconque des revendications précédentes, comprenant en outre un dispositif servant à déterminer un facteur individuel d'étalonnage de chacun des premiers capteurs.

7. Procédé de mesure de la répartition de pression, produite par un objet tridimensionnel, et comprenant les étapes de :

présence d'une pluralité de premiers capteurs non linéaires de force, disposés en un groupement ;  
présence d'un second dispositif de détection de force, ayant une sortie linéaire ou linéarisable, pour la mesure de la force totale appliquée aux premiers capteurs de force ;  
obtention de valeurs mesurées de la force appliquée à chaque capteur du groupement de premiers capteurs de pression ;  
addition des valeurs mesurées, provenant de tous les premiers capteurs de force du groupement ; et  
comparaison de ce résultat avec la sortie provenant du second dispositif de détection de force.

8. Procédé de mesure de la répartition de pression, produite par un objet tridimensionnel, et comprenant les étapes de :

présence d'une plaque sensiblement rigide ;  
présence d'une pluralité de premiers capteurs de force, disposés en un groupement, le groupement étant prévu pour être placé sur un côté de la plaque ;  
présence d'un second dispositif de détection de

force, servant à mesurer la force totale appliquée à la plaque ;  
balayage du groupement de premiers capteurs de force pour l'obtention de valeurs mesurées de la force appliquée à chaque capteur ; 5  
addition des valeurs mesurées, provenant de tous les premiers capteurs de force du groupement ; et  
comparaison de ce résultat avec la sortie provenant du second dispositif de détection de force. 10  
ce.

9. Procédé selon la revendication 7 ou 8, comprenant l'étape d'étalonnage des premiers capteurs de force, en fonction des résultats de la comparaison. 15

10. Procédé selon l'une quelconque des revendications 7 à 9, comprenant en outre l'étape de détermination d'un facteur individuel d'étalonnage de chacun des premiers capteurs. 20

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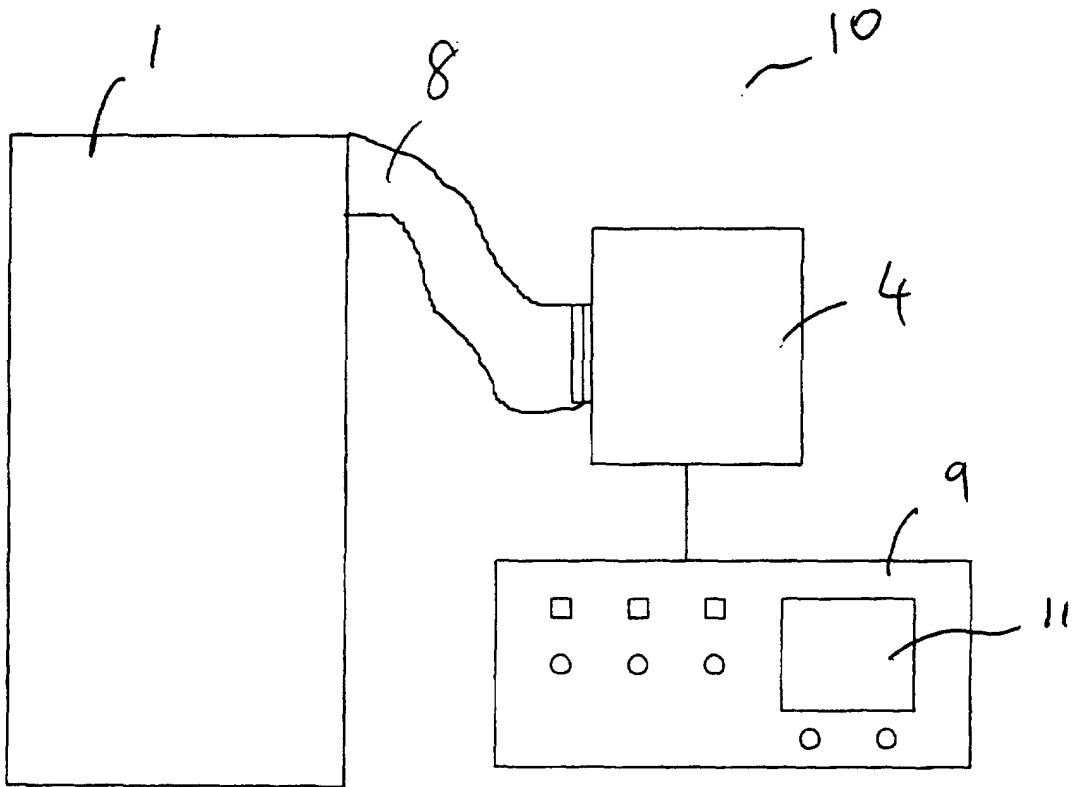


Fig. 1

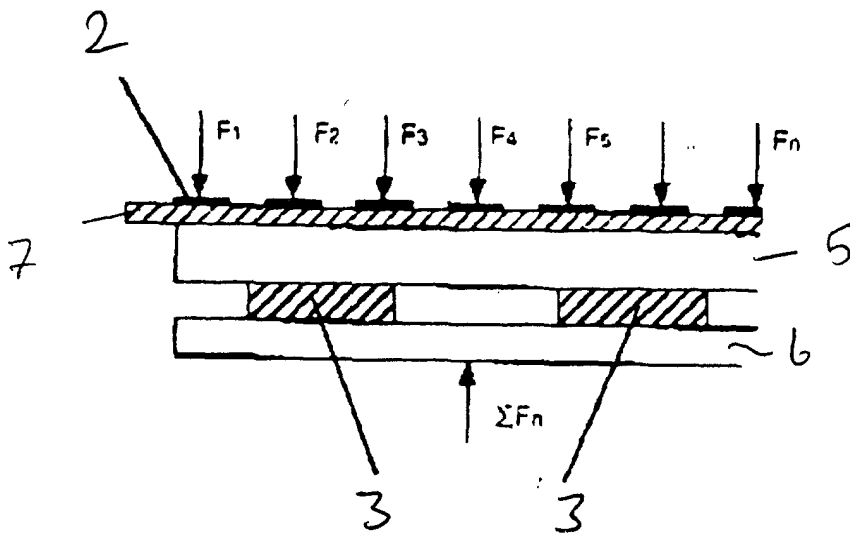


Fig. 2

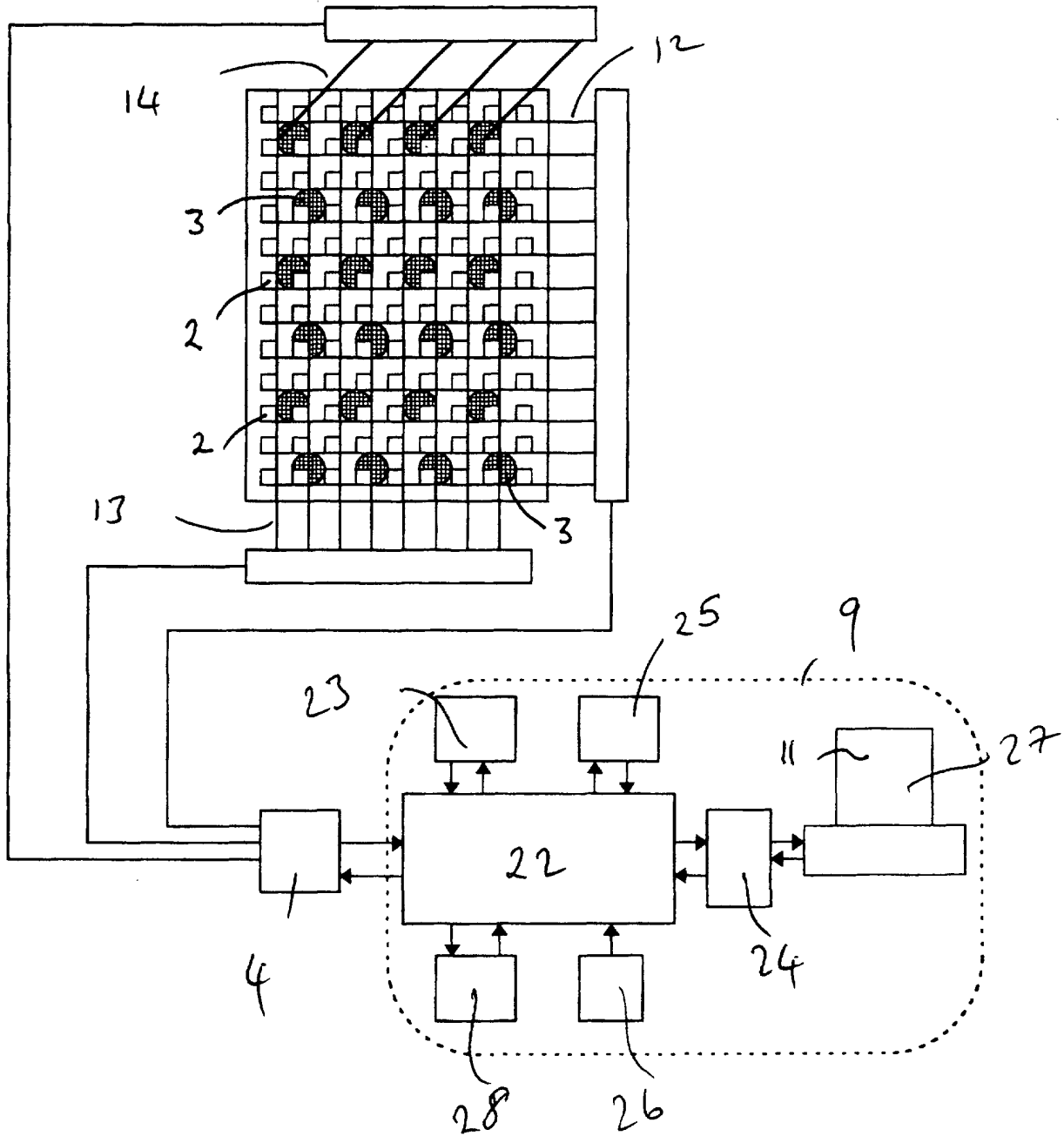


Fig. 3

sensor number	calibration factor
1	1,1
2	0,9
3	0,85
4	1,5
5	2,3
6	1,0
7	0,58
8	0,7
etc	etc

Fig. 4

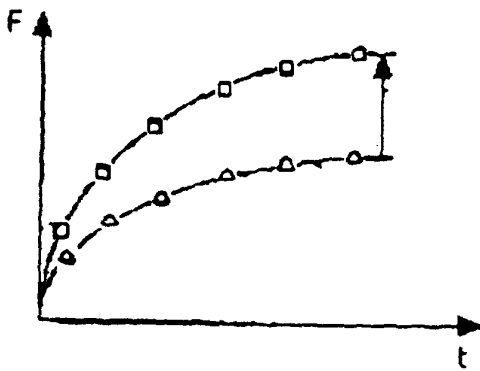


Fig. 5A

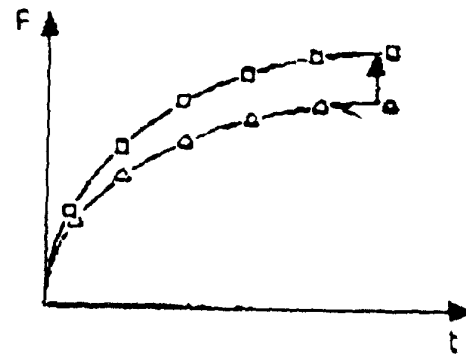


Fig. 5B

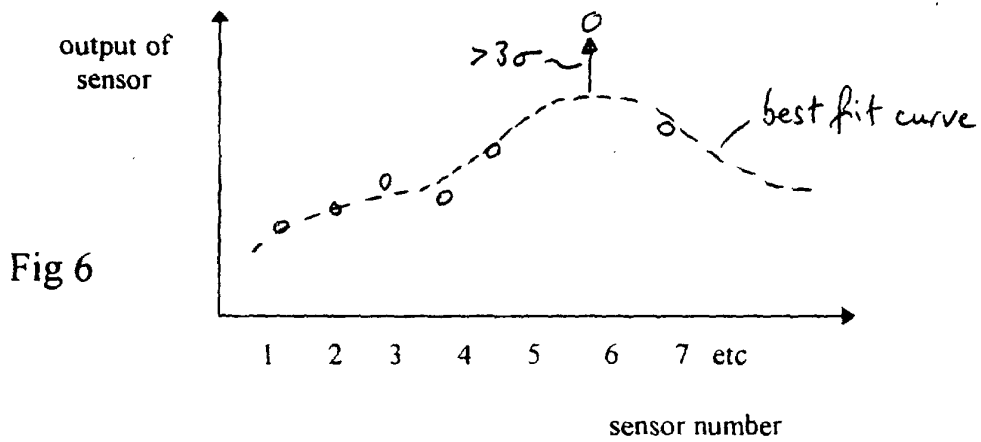


Fig 6

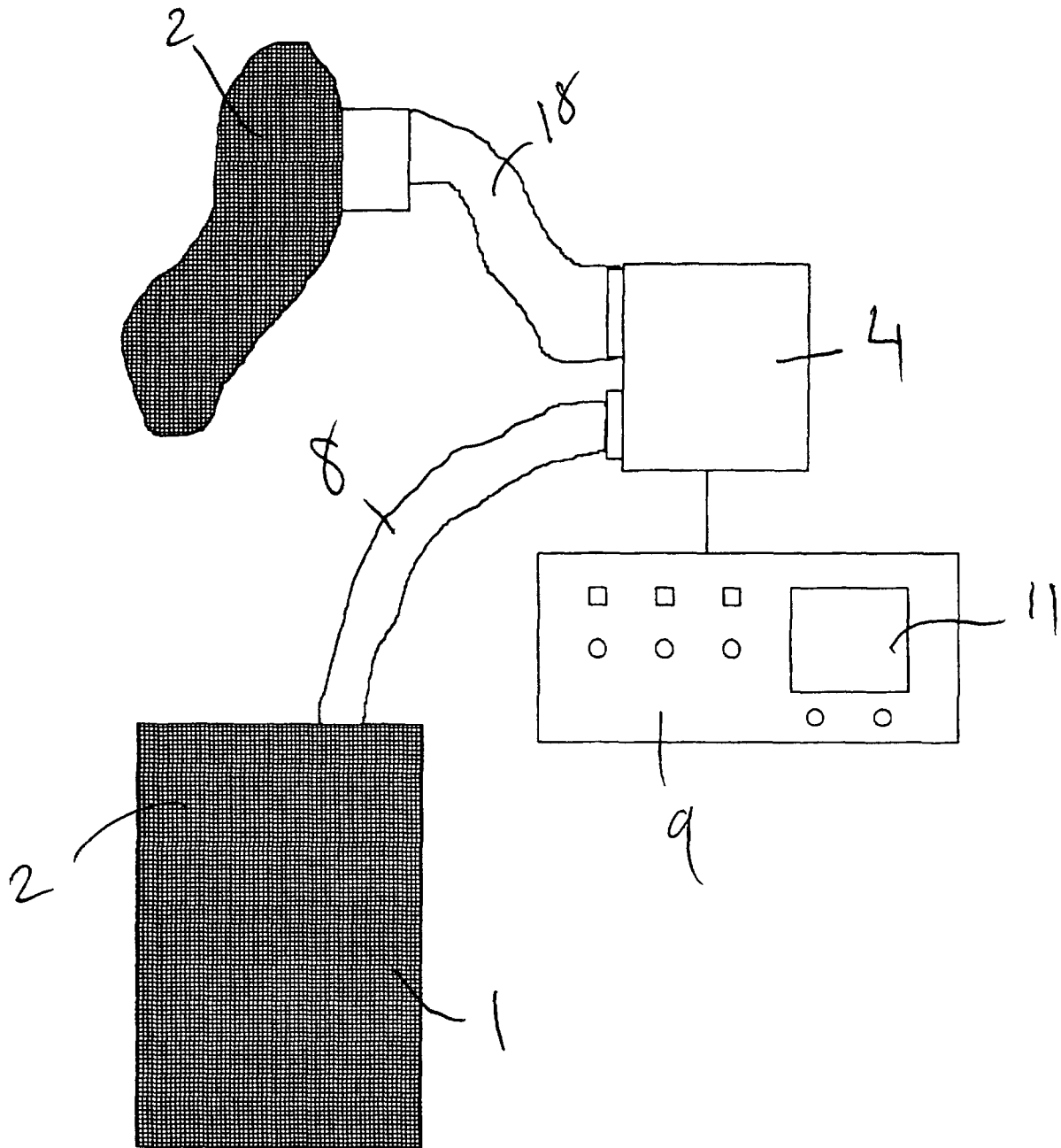


Fig. 7